



A new species of the seasonal killifish genus *Moema* (Cyprinodontiformes: Rivulidae) from the Piraí watershed in the Southwest Amazon basin

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Moema, a genus of the Rivulidae family, currently comprises 20 valid species. Most of these species inhabit temporary pools in the Amazon basin and only one species is found in the upper Paraguay basin. A new member of this genus from the upper Río Madeira drainage is here described. Males of the new species differ from all congeners by the combination of a color pattern consisting of oblique, sometimes chevron-like, irregular rows of red and light blue double-dots on body; dark yellowish to golden pectoral fins with no visible markings; and a stripe pattern on the ventral section of caudal fin with a very narrow black marginal line, intermittent or even absent. The existence of infrageneric species groups within *Moema*, the geographic distribution and taxonomic aspects of the species present in the Ríos Mamoré and Iténez/Guaporé rivers drainages, and the observation of intraspecific aggression between males and amphibious lifestyle in the new species are discussed.

Keywords: Bolivian Amazon basin, New species, Rivulids, Taxonomy, Temporary water bodies.

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Moema, un género de la familia Rivulidae, actualmente comprende 20 especies válidas. La mayoría de estas especies habitan en charcos temporales de la cuenca amazónica y solo una especie se encuentra en la cuenca alta del Río Paraguay. Un nuevo miembro de este género de la cuenca alta del Río Madeira es descrito aquí. Los machos de la especie nueva se diferencian de todos los congéneres por la combinación de un patrón de color de filas irregulares oblicuas, a veces en forma de chevrón, de puntos dobles rojos y azul claro en el cuerpo; aletas pectorales de color amarillento oscuro a dorado sin marcas visibles; y un patrón de rayas en la sección ventral de la aleta caudal con una línea marginal negra muy estrecha, intermitente o incluso ausente. Se discute la existencia de grupos infragenéricos de especies dentro de *Moema*, la distribución geográfica y aspectos taxonómicos de las especies presentes en el drenaje de los Ríos Mamoré e Iténez/Guaporé, y la observación de agresión intraespecífica entre machos y estilo de vida anfibio en la nueva especie.

Palabras clave: Cuenca amazónica de Bolivia, Cuerpos de agua temporales, Nueva especie, Rivúlidos, Taxonomía.

INTRODUCTION

The genus *Moema* Costa was established with the simultaneous description of *Moema piriana* Costa, 1989, as type species, and *Moema portugali* Costa, 1989 in view of three distinctive characters: a lanceolate pectoral fin, a process on the anterior ventral region of the dentary bone, and an elongated ascendant process of the premaxillary bone (Costa, 1990). Subsequently, Costa (1992, 1998) added more diagnostic characters for this genus, e.g., elongated superior extension of preopercle, first epibranchial reduced, long premaxilla and dentary, posterior ventral projection on opercle, broad rostral cartilage, and others. Costa (1998) also proposed the genus *Aphyolebias* Costa considering four diagnosis characters: constricted dorsal section of metapterygoid, posterior extensions on the borders of caudal fin in males, a dark humeral spot, and a black margin on the ventral border of the pectoral fin; with *Moema peruensis* (Myers, 1954) as type species. Five species, i.e., *Moema peruensis*, *M. wischmanni* (Seegers, 1983), *M. rubrocaudata* (Seegers, 1984), *M. staecki* (Seegers, 1987), and *M. obliqua* (Costa, Sarmiento & Barrera, 1996), previously included in *Pterolebias* Garman, 1895, were reclassified in these two genera (Costa, 1992, 1998).

Later, as a result of a phylogenetic analysis combining mitochondrial DNA sequences and morphological characters, *Aphyolebias* was considered a synonym of *Moema* (Costa, 2014). The diagnostic characters suggested previously by Costa (1990, 1992, 1998) have shown to be unsuitable to establish a clear generic limit between both genera, and the geographical range is also largely overlapped. The taxon *Moema* redefined *sensu* Costa (2014) is diagnosed by: 1) the ventroposterior part of the opercle expanded and dorsal section longer than ventral section, and 2) pectoral fin distal section narrow forming a long, pointed tip.

Moema is included in the tribe Rachoviini Costa of the subfamily Rivulinae Myers (Costa, 2014; Loureiro *et al.*, 2018) and comprises 20 valid species: *Moema apurinan* Costa, 2004, *M. beucheyi* Valdesalici, Nielsen & Pillet, 2015, *M. boticarioi* (Costa, 2004), *M. claudiae* (Costa, 2003), *M. funkneri* Valdesalici, 2019, *M. hellneri* Costa, 2003, *M. heterostigma* Costa, 2003, *M. kenwoodi* Valdesalici, 2016, *M. manuensis* (Costa, 2003), *M. nudifrontata* Costa, 2003, *M. obliqua*, *M. pepotei* Costa, 1992, *M. peruensis*, *M. piriana* Costa, 1989, *M. portugali*, *M. quiii* Huber, 2003, *M. rubrocaudata*, *M. schleseri* (Costa, 2003), *M. staECKi*, and *M. wischmanni* (Fricke *et al.*, 2021).

The geographic range of *Moema* species comprises the upper Río Paraguay basin in the Pantanal region, and the drainages of the rivers Purus, Napo, Branco, Madre de Dios, Madeira (Iténez/Guaporé, Mamoré) Ucayali and lower Amazonas in the Amazon basin (Costa, 2003a, 2008; Valdesalici, 2015, 2019; Loureiro *et al.*, 2018). With the exception of *M. heterostigma* from Pantanal region, which is found in temporary swamps (Costa, 2003b), all other *Moema* species inhabit temporary pools in dense Amazonian forests (Costa, 2008, 2014).

The occurrence of five species of the genus *Moema* is reported from the upper Madeira basin in Bolivia. The type material of four of them, *M. obliqua*, *M. claudiae*, *M. beucheyi*, and *M. funkneri*, was collected in Bolivia and they are probably endemic to this country (Costa *et al.*, 1996; Costa, 2003a; Valdesalici *et al.*, 2015; Valdesalici, 2019); the fifth species, *M. pepotei*, is reported from localities near the city of Santísima Trinidad, Beni (Costa *et al.*, 1996; J. Sarmiento, 2020, pers. comm.). A new species of the genus *Moema* collected in the Bolivian lowlands is herein described.

MATERIAL AND METHODS

The fishes were collected with hand net at type locality and maintained a few days in 20 to 50 liter aquaria for observation and photographic record. Specimens were euthanized with 25 ml/l of ethyl-alcoholic clove (*Syzygium aromaticum* flower buds) extract in water and fixed with 4% formaldehyde in water solution for 10 days, washed with water and transferred to 70% ethanol for conservation. Three specimens collected with holotype were conserved separately in 96% ethyl alcohol for posterior molecular analysis, and are cited as non-type material since their morphological characters were not reviewed for the description of the species.

Morphometric measurements were taken point to point with digital caliper (accuracy ± 0.02 mm) to the nearest 0.01 mm on the left side of specimen following the landmarks proposed by Costa (1995). Standard length (SL) is given in mm and the rest of measurements are presented as percentage of SL or, for head measurements, as percentages of head length (HL). Meristic counts (scales and fin rays) follow Costa (1995) and include in fin ray counts all elements. Frequencies of counts are indicated after each value in parentheses and the counts of the holotype are marked with an asterisk. The frontal head squamation terminology follows Hoedeman (1958), and the cephalic neuromasts counts and nomenclature are adapted to *Moema* from that proposed by Costa (2006) for *Austrolebias* Costa, 1998 (Rivulidae: Cynolebiinae).

Color pattern descriptions were based on photographs of live type specimens. The photographs were taken under artificial light (LED 50 W; 4000 lm, 6500 °K, CRI >

80) with the light source at 30–35 cm and 80° to 90° above the living fish. Except trimming, no additional digital corrections of the photographic images were made.

In references to scientific institutions and collections the self-nominative names in original language, or the corresponding acronyms as registered by Fricke, Eschmeyer (2021), are used. For the identification of hydrological units, the Pfafstetter codes defined by Lehner, Grill (2013) are used, accompanied where possible by the name of the corresponding main water body.

Type material is deposited in the ichthyological collection of the Museo de Historia Natural Noel Kempff Mercado (MNKP), Santa Cruz de la Sierra, Bolivia. Morphological, morphometric, meristic and/or color pattern characters of congeners were obtained from Costa (1992, 2003a,b, 2004), Costa *et al.* (1996), Huber (2003, 2021, 2022), Seegers (1984, 1987), Valdesalici (2015, 2019), Valdesalici *et al.* (2015); and comparative material deposited at MHNNKM.

RESULTS

Moema juanderibaensis, new species

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(Figs. 1–5; Tab. 1)

Holotype. MNKP 16539, male, 41.9 mm SL, Bolivia, Santa Cruz, municipality of Santa Rosa del Sara, Juan Deriba ranch, temporary pool (“curichi”) within forest *ca.* 5 km southeast of Santa Rosa del Sara, hydrologic unit 6226987 (Pfafstetter), Pirai watershed, upper Madeira drainage, Amazon basin, 17°07'17.6”S 63°33'23.3”W, 20 Mar 2021, H. A. Drawert.

Paratypes. MNKP 16540, 3 males, 38.2–42.6 mm SL, collected at same locality of holotype, 2 Apr 2021, H. A. Drawert. MNKP 16541, 4 males, 41.3–46.1 mm SL, Bolivia, Santa Cruz, municipality of Santa Rosa del Sara, Juan Deriba ranch, temporary pool (“curichi”) within forest *ca.* 5 km southeast of Santa Rosa del Sara, hydrologic unit 6226987 (Pfafstetter), Pirai watershed, upper Madeira in the Amazon basin, 17°07'17.1”S 63°33'18.8”W, 2 Apr 2021, H. A. Drawert. MNKP 16543, 8 females, 29.9–36.2 mm SL, collected at same locality of holotype, 2 Apr 2021, H. A. Drawert. MNKP 16545, 2 males, 32.2–45.1 mm SL (2 females, 28.1–32.6 mm SL), Bolivia, Santa Cruz, municipality of Santa Rosa del Sara, Juan Deriba ranch, temporary pool (“curichi”) within forest *ca.* 5 km southeast of Santa Rosa del Sara, hydrologic unit 6226987 (Pfafstetter), Pirai watershed, upper Madeira in the Amazon basin, 17°07'19.5”S 63°33'19.3”W, 2 Apr 2021, H. A. Drawert.

Not-types. MNKP 16535, 3 males, collected with holotype, 20 Mar 2021, H. A. Drawert.



FIGURE 1 | *Moema juanderibaensis*, MNKP 16539, holotype, male, 41.9 mm SL (24 days after collection, left side), Bolivia, Santa Cruz, Santa Rosa del Sara.



FIGURE 2 | *Moema juanderibaensis*, MNKP 16539, holotype, male, 41.9 mm SL (2 days after collection, right side), Bolivia, Santa Cruz, Santa Rosa del Sara.

Diagnosis. *Moema juanderibaensis* differs from congeners by a unique combination of the following characters on males: pattern of oblique, sometimes chevron-like, irregular rows of red and light blue double-dots on flanks; dark yellowish to golden pectoral fin with no visible markings (dots or spots); and ventral part of caudal-fin stripe pattern with very narrow black marginal line, intermittent or even absent (*vs.* never in this combination). The new species is distinguished from *Moema apurinan*, *M. beucheyi*, *M. funkneri*, *M. hellneri*, *M. heterostigma*, *M. nudifrontata*, *M. pepotei*, *M. piriana*, *M. portugali*, *M. quiii*, *M. schleseri*, and *M. staecki* by the oblique arrangement of red and light blue double-dots on flanks (*vs.* flank color pattern arranged in horizontal lines or rows of dots). It differs from *M. manuensis*, *M. obliqua*, *M. peruensis*, *M. rubrocaudata*, *M. schleseri*, and *M. wischmanni* by the presence of red dots on flanks mostly arranged in oblique, sometimes chevron-like, rows (*vs.* absence of dots, or arranged in vertical rows or randomly distributed). It is distinguishable from *M. boticarioi*, *M. kenwoodi*, and *M. obliqua* by the absence of dots, spots or any other markings on pectoral fins of males (*vs.* presence of dark reddish-brown dots, few dark green dots or longitudinally elongated dark brown spots); from *M. claudiae* by the absence of black humeral blotch in males (*vs.* presence); and from *M. schleseri* by the ground color of pectoral fins (brown-yellowish to golden *vs.* hyaline) and color pattern of ventral section of caudal fin (thin black marginal line, sometimes intermittent and inconspicuous or even absent, and broad deep orange to red stripe *vs.* ventralmost black stripe broad, and orange stripe with dark red dots). Additionally, it is also distinguished from *M. boticarioi* by the absence of brown dots or other marks on dorsum (*vs.* dorsum with brown dots).

Body form of males is somewhat more slender than in *M. boticarioi*, *M. manuensis*, *M. obliqua*, and *M. wischmanni* (body depth 17.7–21.6% SL *vs.* 23.4–26.1%, 22.2–23.6%, 22–23.6%, and 23.2%, respectively). Caudal fin of males shorter than in *M. boticarioi*, *M. claudiae*, and *M. manuensis* (27.8–36.9% SL *vs.* 39.4% or more of SL); and pectoral fins shorter than in *M. boticarioi* and *M. kenwoodi* (maximum 27.5% *vs.* minimum 29.2% SL). Males differ by having more scales in longitudinal series than *M. manuensis* and *M. rubrocaudata* (34–36 *vs.* 32 and 33 respectively); and more scales in transversal series than *M. boticarioi*, *M. claudiae*, *M. manuensis*, and *M. obliqua* (9–10 *vs.* 8). They also differ by having more pelvic-fin rays than *M. kenwoodi* (7 *vs.* 6), and more anal-fin rays than *M. rubrocaudata* (14–16 *vs.* 13); but fewer anal-fin rays than *M. kenwoodi* and *M. manuensis* (14–16 *vs.* 17 and 17–18, respectively), and caudal-fin rays than *M. claudiae* and *M. kenwoodi* (25–27 *vs.* 28–29 and 31, respectively).

Description. Morphometric and meristic data of holotype and paratypes are presented in Tab. 1. Males larger than females, largest male examined 46.06 mm SL, largest female 36.24 mm SL. Dorsal profile on lateral view straight on head, slightly convex to convex from nape to just anterior to caudal-fin base, in females straighter than in males. Ventral profile on lateral view convex on head, approximately straight to slightly convex from end of lower jaw to end of anal-fin base, section of anal-fin base more convex in females. Caudal peduncle slightly concave. Body slender, subcylindrical, body depth about 1.2 times body width. Greatest body depth on vertical through pelvic-fin base in males, more posterior between vertical through pelvic-fin base and vertical through anal-fin origin in some females. Snout blunt, mouth superior and jaws short.



FIGURE 3 | *Moema juanderibaensis*, MNKP 16543, paratype, female, 36.1 mm SL (1 day after collection, left side), Bolivia, Santa Cruz, Santa Rosa del Sara.

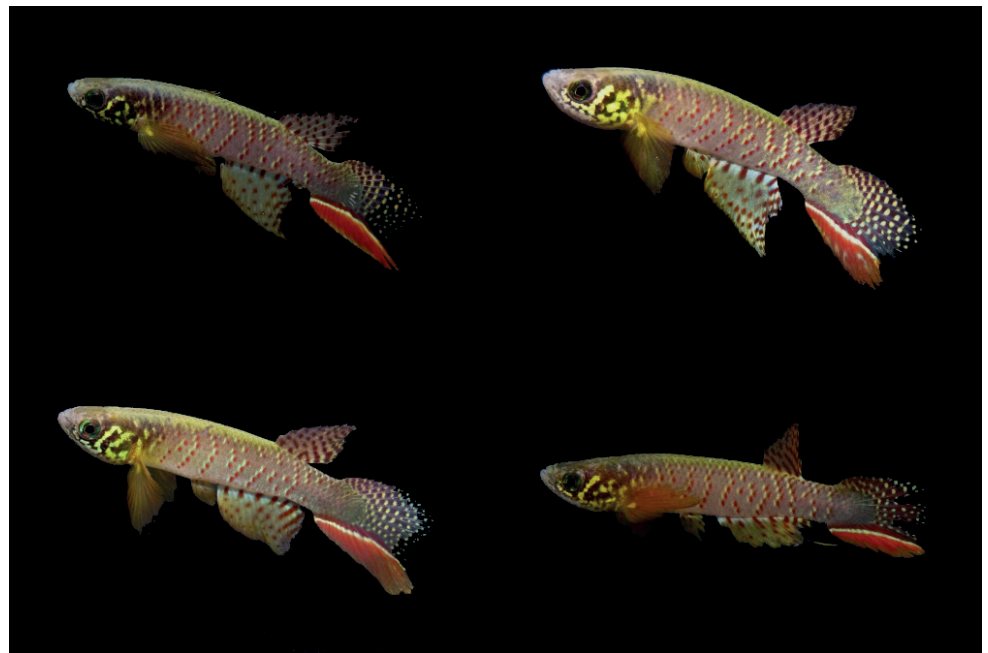


FIGURE 4 | *Moema juanderibaensis*, MNKP 16541, paratypes, males, 41.3–46.1 mm SL (2 days after collection, left side), Bolivia, Santa Cruz, Santa Rosa del Sara.

Dorsal-fin distal section in males slightly pointed to rounded, rounded in females. Dorsal-fin origin at vertical through 7th to 9th anal-fin rays in males and through 7th to 10th anal-fin rays in females. Postero-median anal-fin rays of males longer than posterior and anterior rays, forming pointed tip of anal fin with membrane; anal-fin distal border rounded in females. Caudal fin elliptical; in males with posterior extension forming short sword in ventral part, occasionally barely visible extension in dorsal section. Pectoral fin lanceolate; tip pointed and reaching vertical between pelvic-fin base and 2nd anal-fin ray in males, tip rounded and not reaching vertical through pelvic-fin base in

females. Pelvic fin lanceolate and short; tip pointed and reaching between base of 1st and 3rd anal-fin ray in males; in females rounded to slightly pointed reaching between anus and 3rd anal-fin ray. Dorsal-fin rays 8(1), 9(17), or 10*(2); anal-fin rays 14(3), 15*(11) or 16(6); caudal-fin rays 25(6), 26*(6), 27(6), or 28(2); pectoral-fin rays 14(1), 15(9), 16*(8) or 17(2); pelvic-fin rays 7*(20).

TABLE 1 | Morphometric and meristic data of holotype and paratypes of *Moema juanderibaensis*. 1: MNKP 16539; 2: MNKP 16540, MNKP 16541, MNKP 16545; 3: MNKP 16543, MNKP 16545.

| | Holotype | Paratypes | | Males (n=10 holotype + paratypes) Median (IQR) | Females (n=10 paratypes) Median (IQR) |
|------------------------------------|-------------------|--------------------------|-----------------------------|--|---|
| | Male ¹ | Males ² (n=9) | Females ³ (n=10) | | |
| | | Min–Max | Min–Max | | |
| Standard length (mm) | 41.9 | 32.2–46.1 | 28.1–36.2 | 41.9 (5.1) | 32.1 (1.94) |
| Percents of standard length | | | | | |
| Body depth | 18.8 | 17.6–21.6 | 15.6–20.3 | 19.3 (1.7) | 17.2 (2.3) |
| Caudal peduncle depth | 14.7 | 13.5–17.3 | 12.6–16.4 | 15.3 (1.3) | 14.1 (0.3) |
| Pre-dorsal length | 72.7 | 68.5–73.5 | 69.9–80.4 | 69.7 (3.1) | 74.1 (3.7) |
| Pre-pelvic length | 52.3 | 45.9–49.7 | 45.4–56.1 | 48.4 (2.4) | 51.4 (3.6) |
| Dorsal-fin base length | 12.8 | 11.2–12.9 | 9.1–12.8 | 12.6 (0.6) | 10.6 (1.8) |
| Anal-fin base length | 23.6 | 22.1–25.6 | 17.9–23.8 | 22.7 (1.0) | 18.9 (2.3) |
| Caudal-fin length | 33.6 | 27.7–36.9 | 27.1–35.6 | 34.1 (3.8) | 31.5 (5.4) |
| Pectoral-fin length | 25.7 | 22.9–27.5 | 18.2–22.9 | 24.4 (1.7) | 21.3 (1.7) |
| Pelvic-fin length | 11.7 | 8.5–12.7 | 8.3–13.7 | 11.1 (1.6) | 10.9 (2.2) |
| Head length | 26.7 | 23.4–28.3 | 24.8–29.1 | 26.6 (0.7) | 26.3 (1.4) |
| Percents of head length | | | | | |
| Head depth | 62.8 | 60.8–72.6 | 58.9–66.5 | 63.55 (2.9) | 62.6 (2.1) |
| Head width | 59.9 | 59.2–67.7 | 61.9–68.8 | 62.47 (4.6) | 65.9 (1.5) |
| Snout length | 27.8 | 23.9–32.8 | 19.9–28.6 | 27.40 (3.5) | 22.9 (1.7) |
| Eye diameter | 29.4 | 28.7–35.6 | 29.3–37.3 | 29.50 (2.7) | 32.8 (2.3) |
| Meristic counts | | | | | |
| Longitudinal series scales | 35 | 34–36 | 33–36 | 35 (1.5) | 34 (1) |
| Transverse series scales | 9 | 9–10 | 9–10 | 9 (0) | 9 (0) |
| Circumpeduncular rows scales | 16 | 16–18 | 19–18 | 18 (0.7) | 16.5 (2) |
| Pectoral fin rays | 16 | 14–17 | 15–17 | 16 (1) | 15 (1) |
| Pelvic fin-rays | 7 | 7–7 | 7–7 | 7 (0) | 7 (0) |
| Dorsal fin-rays | 10 | 8–10 | 9–10 | 9 (0) | 9 (0) |
| Anal fin-rays | 15 | 14–16 | 15–16 | 15 (0.7) | 15.5 (1) |
| Caudal fin-rays | 26 | 25–27 | 25–28 | 26 (1.7) | 26.5 (1) |

Scales large, cycloid. Head fully scaled, except on ventral surface at jaws and gular region. Frontal squamation E-patterned; E-scales not overlapping medially, scales arranged in irregular circular pattern around A-scale, which has no exposed margins. Body completely scaled with scales extending over caudal-fin base approximately on anterior 20–25% of caudal-fin length. No scales extending over other fins. Longitudinal series of scales 34(3), 35*(4) or 36(3) in males and 33(2), 34(4), 35(3) or 36(1) in females; transverse series of scales 9*(17) or 10(3); scale rows around caudal peduncle 16*(7), 17(2) or 18(11). Lateral line on body in older males and females complete, with one neuromast per scale. Contact organs on scales of median section of adult male flank, not more than one per scale; no contact organs on fins or fin-rays. Supraorbital neuromasts 3; infraorbital neuromasts 18, preopercular and mandibular series present (Fig. 5).

Coloration in alcohol. Body ground color brownish-grey, darker on head and dorsal region, paler on ventral region and fins; venter whitish. Head on infraorbital and lower opercle regions usually with some dark blotches in males. Dorsal fin with dark dots, sometimes fused to form oblique lines. Anal fin darker on distal border and with dark spots on basal and posterior sections. Caudal fin at medial and dorsal section with dark dots, more conspicuous anterior-dorsally, ventral section with pale stripe sometimes outlined dorsally and ventrally by darker narrow line in males; fin rays darker than membrane. Pectoral fins hyaline, with darker distal border in males. Pelvic fins whitish. Females with less conspicuous markings on fins.

Coloration in life. Males (Figs. 1–2, 4). Body ground color pale light brown to light grey; dorsum darker, brown-greenish; venter white. Flanks with red to dark reddish-brown dots, each preceded by close light blue greenish vertically elongated dot forming “double-dots”; arranged in incomplete oblique rows in some specimens, usually descending forwards below lateral line where they change angle to ascendant forwards forming chevron-like pattern, at least on anterior flank. Side of head brown to



FIGURE 5 | *Moema juanderibaensis*, MNKP 16541, paratype, male, 46.1 mm SL, Bolivia, Santa Cruz, Santa Rosa del Sara. Detail of infraorbital, preopercular and mandibular neuromast series.

dark brown; with golden to metallic green irregular blotches, mostly merged together or connected, forming irregular pattern on opercular region and irregular line following edge of eye in postorbital and suborbital region, usually interrupted in suborbital region. Head ventrally white to pale grey with greenish-brown to dark gray spots, usually fused in reticulated pattern. Iris blue greenish, with dark brown oblique bar crossing center of eye. Dorsal fin light brown to light gray with medial and posterior-basal section lighter, usually pale blue to white; red to dark reddish-brown dots, usually fused to form backwards descending lines, mainly on basal and posterior section of fin. Anal fin dark yellow to greenish-yellow or pale grayish-green in some individuals, which darkens towards distal section; subbasal and posterior-basal parts white to pale light blue; red to dark reddish-brown dots all over the fin, some fused to form 4 to 6 vertically elongated spots on subbasal part and usually also present on posterior section; distal border darker, usually with dark brown to black narrow marginal line. Background coloration of caudal peduncle continues on caudal-fin proximal part covered by scales. Medial and dorsal section of caudal fin reddish-brown fading into hyaline towards distal edge with greenish-light blue dots, greener towards posterior-distal section, usually fused in parallel curved lines on medial and proximal dorsal part. Caudal-fin coloration more intense and darker on dorsal section, sometimes forming dark brown to black border on distal part. Caudal-fin ventral section generally extends posteriorly forming small “sword”, with pattern of horizontal stripes with narrow black marginal line, sometimes inconspicuous or absent; broad deep orange to red stripe, less intense ventrally in most specimens; narrow white to yellow stripe; and narrow reddish-brown to red stripe, approximately continuing line given by the ventral profile of caudal peduncle and dorsally delimiting stripe pattern from medial section of fin. Pectoral fin dark yellowish-brown to golden, without dots or spots. Pelvic fin yellow to yellowish-brown, paler on basal and basal-posterior section; with few red to dark reddish-brown dots.

Females (Fig. 3). Body background color light brown to pale greenish-brown; dorsum darker and venter white. Dark reddish-brown dots on flanks preceded by light brown to yellowish-brown dots forming double-dots, arranged as male pattern but more irregular and spaced. Side of head brown to light brown; with golden to greenish-yellow metallic spots, generally merged or connected on preopercular and opercular region. Head ventrally white. Iris green to greenish-yellow, with dark brown oblique bar crossing center of eye. Dorsal fin hyaline, basal section pale yellowish-brown; with dark brown dots, usually fused in basal section into 2 to 4 elongated spots. Anal fin hyaline, somewhat darker on distal section; with reddish-brown to dark brown dots, usually fused in basal section forming 4 to 6 vertically elongated spots. Caudal fin hyaline, sometimes with inconspicuous reddish-brown to dark brown dots. Pectoral and pelvic fins hyaline with dark golden to pastel yellow basal section.

Geographical distribution. Known only from type locality and surrounding temporary pools in the Pirai watershed (hydrologic unit 6226987), upper Madeira basin, in the southwest Amazon ecoregion (Fig. 6).

Ecological notes. Collected in shallow temporary pools within dense forest, a biotope type locally known as “Curichi”. The water was typically “black-water”, dark brown color and slightly acid (pH 6.4–6.6) probably due to the presence of organic

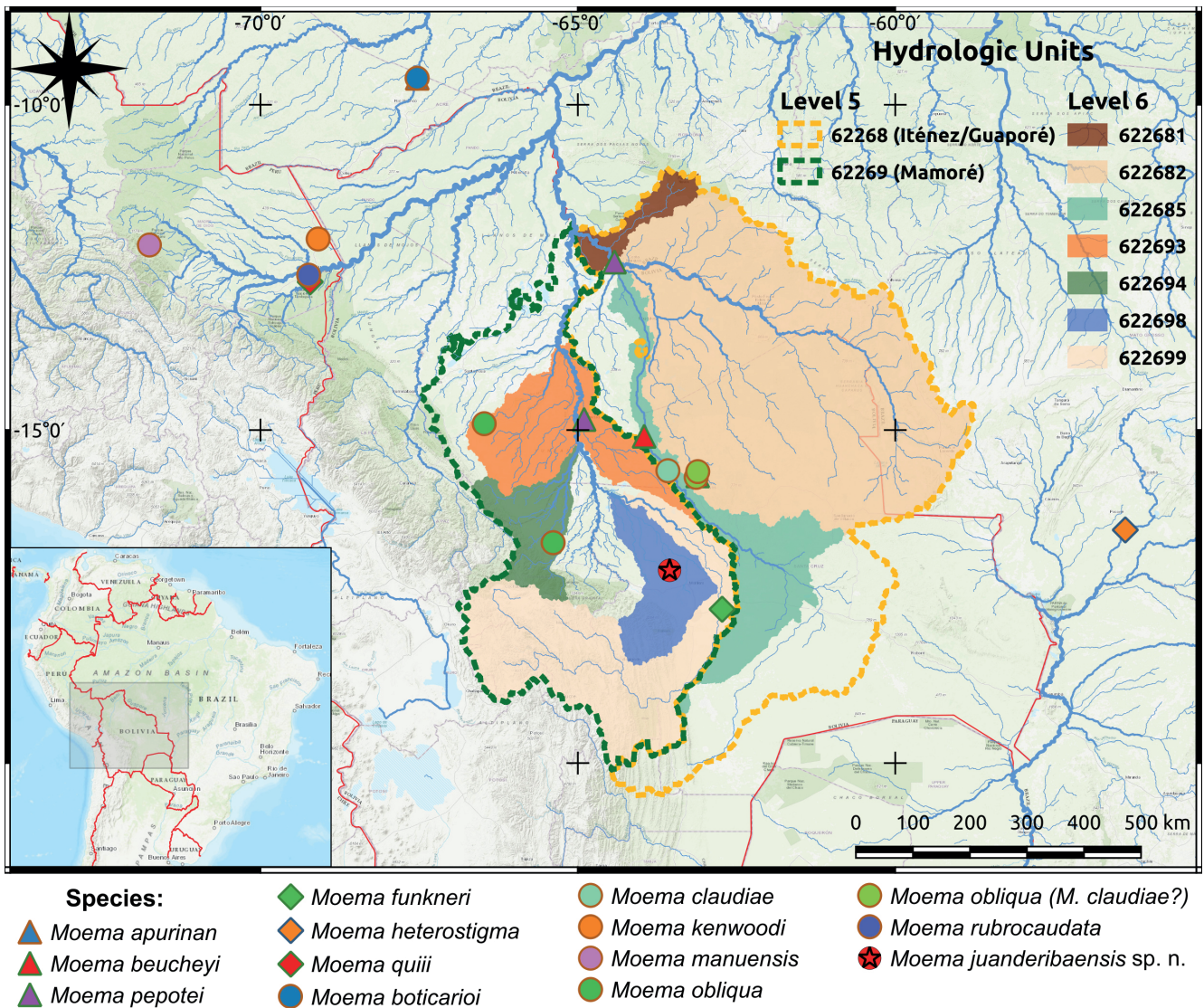


FIGURE 6 | Occurrence localities of *Moema* species in Bolivia and surroundings. Sources: Hydrologic Units from Lehner, Grill (2013); Basemap ESRI World Topo (2022).

dissolved matter, of pluvial origin without detectable flow or fluvial connection. The extension of the pools were not determined (some over 100 m²), largely flooding the surrounding forest; mostly shallow (about 0.05–0.20 m deep) with the deepest sections about 0.40 to 0.50 m deep. The surface was partially covered (about 5–10 %) by floating leaves and plant litter, and poorly lit due to forest canopy coverage shadow. The substratum was composed by a 0.05–0.10 m layer of leaves, other plant litter and mud over compact, dark brown to blackish clay. Aquatic vegetation found was *Nymphaea* aff. *amazonum* (Nymphaeaceae), which grows with submerged leaves in the deeper and better illuminated sections of the pools, and *Heliconia* aff. *marginata* (Heliconiaceae) was found as riparian and “standing” emergent vegetation in the shallow sections. Surrounding vegetation corresponds to a tropical pluvistational semideciduous forest. The only sympatric fish species found was another rivulid of the same genus: *Moema* cf. *beucheyi*.

Only one or two dominant males preserve the whole ventral section of caudal fin with the stripes pattern visible under spatial stress (e.g., collecting bucket, aquarium) in groups of several males or males and females mixed, after a few hours. In other males, this part is mutilated or severely damaged. When this color character is absent (i.e., mutilated fin, juvenile males or females), the aggressions reduces dramatically and are less harmful. In the aquarium, specimens were observed staying attached to the glass above water surface or resting on floating leaves of aquatic plants for several hours, especially at high temperatures or under stress factors (e.g., intraspecific aggression).

Etymology. Named *juanderibaensis* in reference to the name of the ranch “Juan Deriba” where the type locality is situated. An adjective.

Conservation status. *Moema juanderibaensis* is known only from temporary pools within forests in good conservation status and in the vicinity of the type locality. The advance of the agricultural frontier in recent decades and the associated ecological degradation that still persists should be considered as threats to this species. There is no information on distribution, biology, and population trends, so its extinction risk cannot be adequately assessed. Therefore, *Moema juanderibaensis* can be categorized as Data Deficient (DD) according to the International Union for Conservation of Nature (IUCN) categories and criteria (IUCN Standards and Petitions Subcommittee, 2022).

DISCUSSION

The genus *Aphyolebias* is considered to be a synonym of *Moema* by Costa (2014), who argued that they cannot be properly distinguished because the generic diagnostic features are not applicable to some of the newer taxa; they have an overlapping geographic range; and a molecular analysis (Murphy *et al.*, 1999) supporting that *M. staeki* is more related to *M. peruensis*, the type species of *Aphyolebias*, than to *M. piriana*, the type species of *Moema*. On the other hand, Costa (2014) gave evidence that the presence of two shared morphological characters (opercle with posteroventral section expanded and dorsal section longer than ventral section, and pectoral fin with distal section narrow forming a long pointed tip) can be used for diagnosing one clade, *Moema sensu* Costa (2014). However, within the genus *Moema sensu* Costa (2014) there are four species groups, clearly distinguishable by flank color pattern. The first group contains species with a flank color pattern always arranged horizontally, composed by dots following interrupted lines – a character shared with other rachovine rivulids, i.e., *Trigonectes* Myers, 1925 and *Neofundulus* Myers, 1924 – and which is also visible in preserved specimens. *Moema apurinan*, *M. beucheyi*, *M. hellneri*, *M. nudifrontata*, *M. piriana*, *M. pepotei*, *M. portugali*, *M. schleseri*, and *M. staeki* belong to this species group. The second group includes just one species of medium size, *M. peruensis*, with a flank color pattern formed of broad vertical bars, darker than the thinner interspaces and without dots as part of the color pattern. The third group contains species with a combination of the two previous color patterns: horizontally arranged rows of dots over vertical bars as background color pattern. Compared with the other congeners, they are usually larger in size, have a larger and more pointed snout, and higher meristic values in squamation

and fin rays. The species of this group are *M. funkneri*, *M. heterostigma*, and *M. quiii*. The fourth group comprises the smaller species with a flank color pattern of dots arranged transversally, usually as oblique rows, or sometimes even without any arrangement; the color pattern is normally inconspicuous or not present in females. *Moema boticarioi*, *M. claudiae*, *M. kenwoodi*, *M. manuensis*, *M. obliqua*, *M. rubrocaudata*, *M. wischmanni* and the new species described herein belong to this species group.

The geographic distribution of the *Moema* species from the upper Madeira basin in the Mamoré and Iténez/Guaporé drainages (hydrologic units 62269 and 62268, respectively), the most southern tributaries of the Amazon basin, is poorly referenced and still unclear (Fig. 6). Of the species with color pattern arranged in transverse rows of dots, *M. claudiae* is only reported from the type locality (Carvajal *et al.*, 2016a) in the upper Itonamas River watershed (hydrologic unit 6226851), an affluent of the Iténez/Guaporé; *M. obliqua* is reported from the type locality in the Apere River watershed (hydrologic unit 6226932) in the middle Mamoré drainage, and mentioned to be present in the Chapare region (hydrologic unit 622694) (Carvajal *et al.*, 2016b) in the western upper Mamoré drainage; and the *M. juanderibaensis* described herein was collected also in the upper Mamoré drainage, but on the East side, in the Pirai watershed (hydrologic unit 6226987). The presence of *M. obliqua* near Urubichá in the Río Blanco watershed (hydrologic unit 6226822), Iténez/Guaporé drainage, reported by K. Osinaga and J. Cardona in April 2003 (GADSC, 2011) probably correspond to specimens of *M. claudiae* considering the proximity to the type locality (about 50 km *vs.* at least 350 km), hydrologic connection (Iténez/ Guaporé drainage *vs.* Mamoré drainage), surrounding terrestrial ecosystem (Amazon forest *vs.* temporary inundated savanna), and that the description of the species by Costa (2003a) was published later, in the second semester of that year. From the species belonging to other color pattern groups, *M. beucheyi* is reported from the Itonamas and Río Blanco watersheds (hydrologic units 6226851 and 6226822), in the Iténez/Guaporé drainage (Valdesalici *et al.*, 2015); *M. pepotei* from type locality near Costa Marques, Brazil, (hydrologic unit 6226817) in the Iténez/Guaporé drainage (Costa, 1992), and from near Santísima Trinidad, Bolivia, (hydrologic unit 622693) in the Mamoré drainage (Costa *et al.*, 1996; J. Sarmiento, pers. comm., 2020); while *M. funkneri* is reported only from Río Grande watershed (hydrologic unit 622699) in the upper Mamoré drainage (Valdesalici, 2019).

The known species of *Moema* present in the Mamoré and Iténez/Guaporé drainages can be distinguished considering simple color pattern characters of the males, with exception of *M. beucheyi* and *M. pepotei* where the non-meristic diagnostic characters to differentiate both species are unclear. Following Valdesalici *et al.* (2015) “*M. beucheyi* differs from [...] *M. pepotei* by presence of a black humeral blotch (*vs.* absence) and presence of a black stripe on the anal fin margin (*vs.* absence)...”, but they also indicate that the humeral spot in *M. beucheyi* is relatively small and “hard to be discerned in some specimens”. On the other hand, Costa (2003b), describer of *M. pepotei*, in the diagnosis of *M. heterostigma* indicates the presence of a black humeral spot in *M. pepotei*. In any case, the description of *M. pepotei* is based on a single, poorly preserved, specimen (Costa, 1992; Valdesalici, 2019; Valdesalici *et al.*, 2015) and the “... live color pattern [of this species] has not yet been recorded” (Valdesalici *et al.*, 2015); so color patterns are probably useless as diagnostic characters for this species. By now, *M. pepotei* can only be distinguished from *M. beucheyi* by a lower number of longitudinal scales (35 *vs.* 38–39),

transverse series of scales (9 *vs.* 12–13), circumpeduncular rows of scales (16 *vs.* 21–22) and anal-fin rays (17 *vs.* 18–19), but regarding that the description of *M. pepotei* is based on just one specimen (possibly sub-adult in view of relative low SL and elliptical shape of caudal fin), this meristic values could not be representative for the species. Furthermore, as shown in a photograph available at CAS (2021), the holotype of *M. pepotei* (Fig. 7) has clearly higher values in squamation counts than indicated in the description by Costa (1992) and they seem to be similar to the values indicated for *M. beucheyi*. The facts that the Itonamas and Río Blanco rivers drain into the Iténez/Guaporé close to the type locality of *M. pepotei* (less than 20 km upstream) (Costa, 1992) and that the reported occurrence localities of *M. beucheyi* are located between this type locality and the occurrence locality of *M. pepotei* in the Mamoré drainage suggest that they would also have an overlapping distribution area. A possible synonymy should be discarded with the revision and comparison of primary type material and a representative stock of topotypes from both species.

It is known that in rivulids females show preferences for certain male phenotypes (*e.g.*, color patterns) at intersexual selection; and males, at intrasexual selection, engage in ritualized aggressive contests where one male charges and bites the other one targeting the fins causing often evident injuries (Passos *et al.*, 2015). As observed, the orange to red stripe in color pattern of the caudal fin of males seems to trigger direct aggression by other males in *M. juanderibaensis* in some situations. The reason or function of this behavior has not been studied, but it is probably related to sexual selection. Analogous color patterns in the caudal fin are also present in most of the congeners and other rachovine rivulids (*e.g.*, *Micromoema xiphophora* Thomerson & Taphorn, 1992, *Neofundulus*, *Pterolebias phasianus* Costa, 1988, *Rachovia* Myers, 1927, *Renova oscari* Thomerson & Taphorn, 1995), so possibly a similar behavior could be observed in other species.

Amphibious lifestyles are documented for at least 13 species of four genera in the family Rivulidae, and in at least 34 species of the order Cyprinodontiformes (Turko, Wright, 2015). The behavior of voluntary emersion for long periods of time is reported by aquarists in many more species (Livingston *et al.*, 2018), so amphibiousness could



FIGURE 7 | *Moema pepotei*, CAS-SU 63604, holotype, male, 45.4 mm SL, Brazil, Rondônia, Forte Príncipe da Beira (on Bolivian border). Source: CAS Ichthyology Primary Types Imagebase.

be relative common in rivulids. The herein described species was observed to stay attached to the glass above water surface or lying on floating leaves of water plants for several hours. This behavior was previously not reported in *Moema* and suggests that evolutionary adaptations for an amphibious lifestyle are also present in this genus.

Comparative material examined. All from Bolivia. *Moema beucheyi*: MNKP 2954, 1, 59.4 mm SL. *Moema* aff. *claudiae*: MNKP 2994, 5, 27.8–43.3 mm SL. MNKP 5505, 2, 39.3–40.1 mm SL. *Moema funkneri*: MNKP 3720–2, 5, 34.4–53.2 mm SL. *Moema* aff. *obliqua*: MNKP 4310, 5, 34.2–47.4 mm SL. *Moema* sp.: MNKP 2956, 2, 33–40.4 mm SL.

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AUTHORS' CONTRIBUTION

Heinz Arno Drawert: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing–original draft, Writing–review and editing.

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